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MARS 2 AND 3 -- INTERPLANETARY STATIONS OF THE USSR

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ABSTRACT. The article describes the design and construction of the Soviet Mars 2 and 3 probes, with comprehensive details on instrumentation and orbital parameters.

On 27 November 1971, after a flight of 192 days, the automatic interplanetary /41* station Mars 2 went into orbit around the planet Mars at approximately 2119 CET (Central European Time). This operational maneuver was not controlled from the Earth, since the corresponding radio signal would require a total of 16 minutes due to the great distance between the Earth and the spacecraft. The orientation and position of the station in space and relative to Mars was controlled by an independently functioning control system used for the first time aboard the Mars 2 station; the system consisted of an astronavigation system and an electronic computer. The data obtained in this fashion were automatically fed into the onboard computer which calculated the necessary spherical angle of curvature, magnitude of direction of the necessary braking pulse band gave the appropriate commands to ignite the course engine. The installation of such independent astronavigation systems together with onboard computers in automatic interplanetary stations of the future will increase the possibility of reaching the farthest planets of our Solar System.

Even as it was approaching Earth's neighbor planet, Mars 2 had fired a special container that rapidly separated from the interplanetary station to fall on the Martian surface to become the first man-made object to make a hard landing on Mars. The container delivered a pennant with the coat of arms of the Soviet Union to Mars. Mars 2 entered the planned orbit around Mars, whose initial parameters were as follows: periapsis, 1380 km; apoapsis, 2500 km, angle of inclination of the plane of the orbit to the Martian equator: 48 degrees 54 minutes, period of revolution 18 hours. The second artificial Mars satellite

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*Numbers in the margin indicate pagination in the foreign text.

is carrying out its principal task to the complete satisfaction of the scientists on Earth -- the study of relief of the surface structure of the planet. For this purpose, the Mars 2 station is equipped with a television objective with a high resolving power, which can cover enormous stretches of the Martian surface to reveal details measuring 10 to 100 m in length. For comparison's sake observations of Mars carried out with a telescope on Earth cannot reveal objects on Mars that are smaller than 50 km across! In addition, Mars 2 is also carrying out a number of important research projects: highly sensitive instruments are measuring the parameters of the Martian atmosphere, its gas constituents, the pressure conditions in the gas envelope (how pressure varies with altitude) and recording the temperatures on the night side of Mars. In this fashion, a heat chart of the planet can be constructed on Earth. Special apparatus aboard the Mars 2 is "feeling" the relief of the planet from the aerocentric orbit and determining which minerals and types of rocks can be found on this heavenly body and of what chemical elements they are composed. Moreover, an analysis of the behavior of the satellite orbit of Mars 2 can provide an idea of the gravitational conditions of the planet, its shape (it is more markedly oblate at the poles than our Earth) and it determines the inhomogenity of the mass distribution in its interior.

SOME MARS DATA

Mean distance from the Sun: 227.9 million km (as compared to Earth -- 149.63 million km).

Time required to revolve around the Sun (1 Martian year): 686.98 days (Earth: 365.257)

Inclination of orbit relative to the plane of the Earth's orbit (ecliptic): 1.8 degrees

Duration of axial rotation (length of a Martian day): 24 hours 37 minutes 22.7 seconds (Earth: 23 hours 56 minutes 4.1 seconds).

Average diameter of Mars: 6664 km (Earth: 12,742 km), i.e., 53.2% of the diameter of the Earth.

Mass: 1/10 of the mass of the Earth (0.0169).

Average density: 3.96 g/cm^3

Gravitational acceleration at the surface of Mars: 376 cm/sec^2 (Earth: 982).

Yearly average temperature: -15°C.

Number of natural satellites: 2 -- Phobos, 18 km in diameter, average distance from Mars -- 6440 km; Deimos, 8 km in diameter, average distance from Mars -- 23,500 km (Earth's Moon: 3476 km/384, 321 km).

Inclination of the Martian equator with respect to the plane of the orbit: 23 degrees 59 minutes (Earth: 23/27)

First Landing On Mars

While Mars 2 was circling around Mars for the second Earth day on 29 November 1971 at 1900 CET, the Mars 3 automatic station was 138.3 million km from Earth and approximately 2 million km from Mars. At this time it had already covered 472 million km through space since its launching. On 2 December 1971 after 188 days flying time, Mars 3 was 70,000 km distant from the planet Mars, and had therefore come into the sphere of influence of the target planet. Then, similar to the situation aboard Mars 2, the onboard computer gave the station the command to begin the final phase of the flight: the space probe was first turned 180 degrees on its lengthwise axis in order to aim the rocket motor opposite to the direction of flight and thereby achieve a maximum braking effect. When this had been done, the engine was ignited at a predetermined moment. It functioned for exactly the time required. Then Mars 3 began the landing maneuvers for the special landing section. The batteries of solar cells were still supplying the chemical power sources of the Mars 3 landing craft with the necessary supply of energy. A few minutes later, the special landing craft, equipped with scientific instruments, separated exactly on time and commenced to descend to the surface of Mars under the increasing force of attraction of the planet.

From this point on, each of the 2 parts of the Mars 3 station executed an independent flight program. The Mars 3 orbital station (the mother ship) continued its flight after the successful separation of the landing craft and entered orbit around Mars with the following initial parameters: periapsis = = 1500 km, apoapsis = 60,000 km, period of rotation = 11 days. This sharply pronounced difference in the orbit of Mars 2 and Mars 3 is of extreme importance for the transmission techniques used between the vicinity of Mars and the Earth.

Like a glowing meteor, the Mars 3 landing craft followed a ballistic flight path at a velocity of 6 km/sec (i.e., 21,600 km/h) and entered the lower layers of the Martian atmosphere at a very flat angle with respect to the local horizon with a high degree of accuracy. At this moment, the Earth and Mars were approximately 145 million km apart.

In the hermetically sealed interior, the air conditioning system provided "room temperature" despite the frictional heat created by the shock wave ahead of the landing craft. Most of the significant braking effect of the entrance into the very thin Martian atmosphere was due to the very high arrival velocity as well as the broad leading surface of the landing craft. Under terrestrial conditions the method of using this type of landing technique has been employed in recovery of probes and Soyuz spacecraft.

The g-forces gradually diminished and when the velocity was reduced to very low levels by aerodynamic braking, a command from the programmed timer separated /42
the cover of the landing craft and a small stabilizing parachute was deployed. At the same time the antennas for radio communication with the Mars 3 mother ship were extended. After the rate of fall had been decreased so further, a newly designed and heat-resistance special parachute opened at a short distance from the surface of Mars. An ordinary parachute made of conventional polymer substances cannot be used in the Martian atmosphere, since it would simply "evaporate". In this new parachute design, attention had also to be given to the hurricane-like winds that roar across Mars at the rate of 130 m/sec. The scientific laboratory of Mars 3 settled softly through the Martian atmosphere to the surface of the planet. The type of landing that employs the use of a braking engine was not used in Mars 3 since it would have meant too high a fuel supply and a consequent reduction of the scientific payload. Shortly before the landing, the landing section automatically dropped all excess ballast as well as the braking chute. This was a safety measure used because of the storms that constantly blow across Mars. The landing craft settled softly into the sandy soil of the planet Mars, in the middle of a crater in a desolate wasteland, precisely in the predetermined area in the southern hemisphere of Mars -- in the Mara Sirinum. A special shock absorber system ensured that the Mars 3 landing craft would come down in this fashion despite the storm that was in progress and

that its sensitive apparatus would be in functioning condition. The landing site itself has the aerographic coordinates 45 degrees southern latitude and 158 degrees aerographic longitude, and is located between the 2 bright Martian spots or Martian continents, Phaethontis and Electris. This target area is one of the most interesting regions on the Martian surface. It is a smooth hollow with a diameter of approximately 1500 km. The narrow segment of the floor, which was later captured by the Mars 3 television camera on the landing craft, showed a smooth surface. On the other hand, the vicinity of the hollow is filled with craters. On the other hand, the transitional area between these 2 soil formations is rough and covered with ridges. In this landscape in the Martian world, it was midsummer when the first spacecraft from Earth landed on the Red Planet.

Immediately after the landing the landing craft, which had no strong transmitter or large antenna of its own, used the apparatus aboard to transmit measured values, information and (by means of a panoramic camera) pictures from the surface of Mars. These impulses were picked up by the Mars 3 mother station in orbit around Mars and stored by its onboard recording mechanisms. One day later, when the ground stations in the territory of the USSR were again in direct line of sight by radio with the Mars satellite, they were sent after amplification to the Center for Space Communications. It was then discovered that the television pictures originating from the surface of Mars had suddenly ceased shortly after the beginning of photography. Radio transmission of the other data from Mars 3 to Earth took place during the period from 2 to 5 December 1971. The principal tasks of the landing craft of Mars 3 included the study of the composition of the Martian atmosphere, the search for possible existence of water vapor and the study of the interaction between the conditions on Mars and the solar winds.

Technical Data On Mars 2 and 3

The Mars 2 and Mars 3 automatic interplanetary stations are of similar design and equipped with systems for independent control and orientation, radio control orbital measurement, transmission of data, power sources, automatic devices, temperature regulators, radio devices, program time measuring devices, engines and a complex of scientific apparatus.

As far as the construction is concerned, the Mars stations consist of the following principal components: instrument chamber, block consisting of the fuel holder for the engine, correcting engine with automatic elements, solar cell batteries, antenna power supply, radiators for temperature regulaticn.

The instrument chamber is intended for carrying the onboard systems of the station and protecting them against conditions in space. Outside this chamber, optical electronic devices in the system for astroorientation are focused on /43
the Sun, the Earth and a star (Canopus, Sirius), as well as systems of automatic navigation and scientific apparatus.

The instrument chamber is part of the block of the fuel container for the engine, serving as the main supporting element of the spacecraft. In the lower part of this block there is mounted an engine. At the top there is a connecting piece by which the landing craft is connected to the Mars station. The plates of the two solar batteries, consisting of quartz photocells, as well as a high-gain parabolic antenna and a directional antenna are mounted on the block of the fuel carrier. The radiators of the system for temperature regulation are mounted on a carrier for supporting the solar cell batteries. These plates themselves carry some of the scientific apparatus, 2 antennas for radio communications between the station and the landing craft, an antenna for the carrying out of the Soviet-French "Stereo 1" experiment and the microdri`, of the system for orientation and stabilization. To study the planet Mars from the orbit, the Mars 2 and Mars 3 stations were equipped with a special complex of scientific apparatus for studying the atmosphere and the surface of Mars. This complex includes the following:

-- an infrared radiometer with a measurement range from 8 to 40 microns for the preparation of a chart of the temperature distribution on the Martian surface.

-- a device for determining the nature of the surface relief on the basis of the changing amounts of carbon dioxide on the line of sight. The amount of carbon dioxide is determined with the aid of an infrared photometer on the basis of the intensity of the absorption band at 2.06 microns.

-- a device for determining the water vapor content for the spectral method, using the nature of the absorption on the 1.38 micron line.

-- a device for studying the reflectance of the surface and the atmosphere in the visible region of the spectrum from 0.3 to 0.6 microns with the aid of a visible light photometer.

-- a device for determining the radio brightness temperature of the surface in the 3.4 cm range, determination of its electrical conductivity and the temperature of the surface layer at a depth of up to 30 to 50 cm.

-- a device for determining the density of the upper layers of the Martian atmosphere, the content of atomic oxygen, hydrogen and argon with the aid of an ultraviolet photometer.

-- two television cameras with different lens apertures, allowing large--area pictures to be taken covering a considerable area of the planet Mars, and also making it possible to photograph the surface with a sufficiently high degree of résolution from various distances. The axes of visibility of both cameras and the scientific instruments used for studying the features of the planet are parallel to one another making it possible to carry out investigations simultaneously and to photograph the selected segments of the Martian landscape.

The Mars 3 Landing Craft

The Mars 3 landing craft which reached the surface of the planet on 2 December 1971 is an automatic Mars station. It is provided with systems and devices which provide for separation of the craft from the instrument section of the Mars 3 station (the mother ship), its transition to a landing path to the planet, braking, descent to the atmosphere and the soft landing on the surface. The landing apparatus consists of the automatic Mars station (AMS), the instrument and parachute container, the aerodynamic braking shield and the connecting framework.

The connecting framework supports a solid fuel rocket engine for shifting the landing craft from the flypast orbit to the landing orbit as well as aggregates of the system for automatic control to ensure the stabilization of the landing craft after it separates from the mother ship.

Captions of Figures Not Reproduced.

The Automatic Interplanetary Research Station Mars 3 of the USSR After Final Assembly. The solar panels are deployed here (right and left). To the left of the parabolic dish of the high-gain antenna and on the housing of the station there are various instruments and devices.
This Figure Also Shows the Mars 3 Interplanetary Station In the Course of Construction. Here, however, the solar panels have been folded for launching. The automatic landing capsule is at the top of the apparatus. The instrument chamber and the nozzle of the rocket engine are visible at the bottom.

The instrument and parachute container has the shape of a torus. It is located in the upper section of the AMS and connected to it by elastic cords. It contains the parachute and the auxiliary chute. The container supports the operating mechanism for the auxiliary chute, the braking mechanism for the soft landing, the mechanism for deploying the chute, antennae for the radio-altimeter, antenna for radio communication with the mother ship as the latter orbits Mars and scientific instruments. The barrel-shaped braking shield is used for aerodynamic braking of the landing craft in the Martian atmosphere and /44 to protect it from the resultant high temperature.

The automatic Mars station contains a hermetically sealed instrument chamber which carries the apparatus of the automatic control system, the radio instrumentation and the distance measurement, as well as units of scientific apparatus and a panaramic television camera. On the outside, the scientific instruments are equipped with devices for deployment, antennas for the radio system, systems for switching the station over to the correct operating mode after landing. The necessary sequence of individual actions in the functioning of the system are ensured by the program timer.

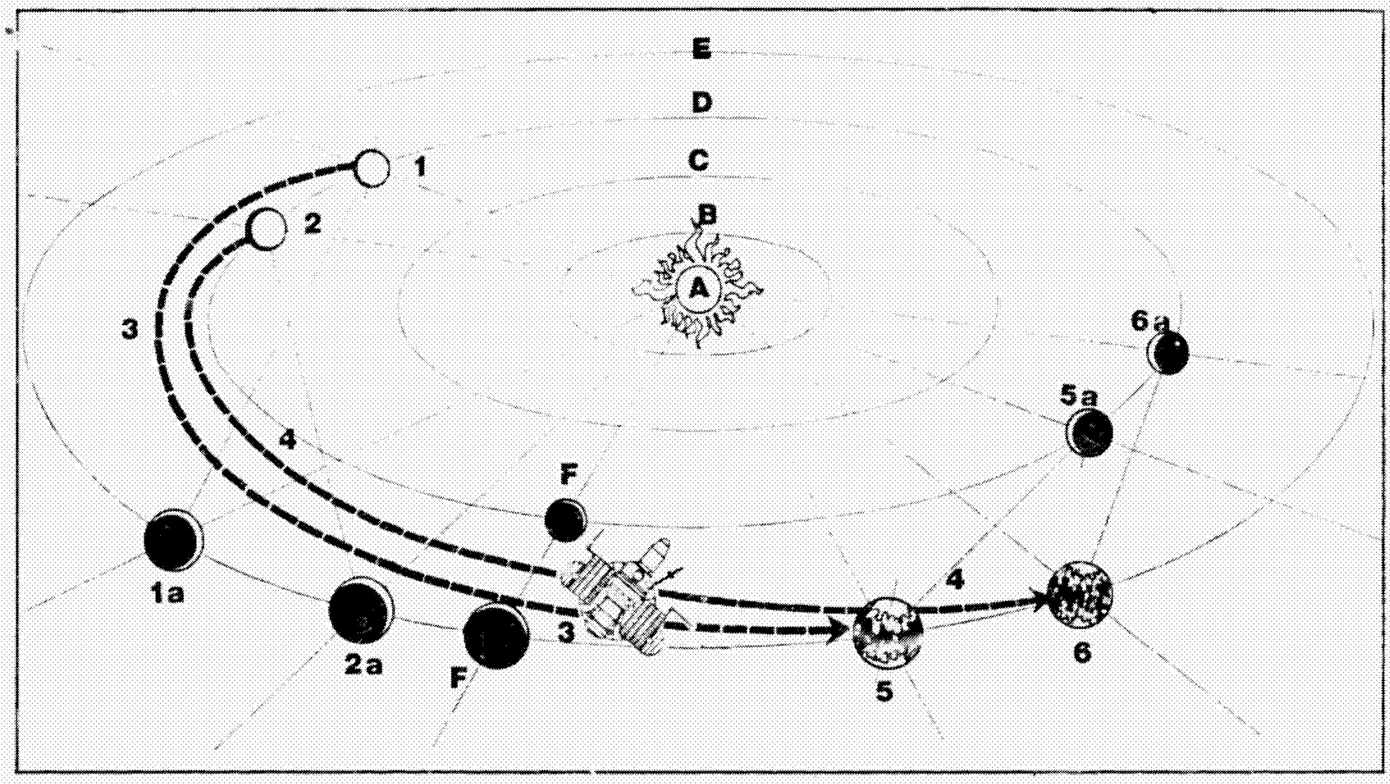
The system for temperature control of the landing craft of the Mars 3 station consists of a vacuum heat insulation, a radiational heater with variable surface, which regulates the temperature prevailing inside the apparatus, and an electrical heater. The scientific equipment in the landing capsule of the automatic station Mars 3 consists of the following:

-- an apparatus for measuring temperature and pressure of the atmosphere;

-- the mass spectrometric determination of the chemical composition of the Martian atmosphere,

-- the measurement of the wind velocities on the planet,

-- the determination of the chemical composition and the physical-mechanical characteristics of the surface layer, as well as the panoramic photography using the television camera.



Positions of the Earth and Mars During the Flight of the Mars 2 and 3 Automatic Stations To Mars (Shown Schematically):
A = Sun, B = Orbit of Mercury, C = Orbit of Venus, D = Orbit of the Earth, E = Orbit of Mars, F-F' = Major Opposition On 10 August 1971.
1 = Position of the Earth on May 1971, launching date of Mars 2.
1a = Position of Mars on launching date of Mars 2.
2 = Position of the Earth on May 28, 1971, launch day of Mars 3.
2a = Position of Mars on launch date of Mars 3.
3 = Flight path of Mars 2 station.
4 = Flight path of Mars 3 station.
5 = Position of Mars on 27 November 1971, the date on which Mars 2 entered an orbit around Mars.
5a = Position of the Earth on arrival day of Mars 2 (192 days after the launch).
6 = Position of Mars on 2 December, the date of the soft landing on Mars by Mars 3.
6a = Position of the Earth on the arrival day of Mars 3 (188 days after launching).

Onboard Systems of Mars 2 and 3

The control system consists of the orientation system, a gyroscopic flywheel which ensures the stability of the station set in space (gyrostabilized platform), a digital computer installation and a system for automatic navigation in space.

The orientation system turns itself on when the station separates from the carrier rocket and functions during the entire flight. The optical-electronic apparatus determines the position of the station with respect to the Sun and the gas-jet microdrive is used to orient the station in such a fashion in space that the normal functioning of the system for temperature regulation, power supply, etc. will be assured. The automatic control system ensures that the station can be stabilized and controlled during the function of the last carrier stage, during correction in orbit and during braking.

The radio technical onboard complex makes it possible together with the corresponding ground control and measurement points to carry out orbital measurements, receive command for controlling the station systems, transmit telemetric and photograph-television information, and to receive detailed data from the landing craft and to record it so that it can be transmitted later to Earth.

Radio communication of the mother ship with Earth is accomplished by means of 2 radio channels, one narrow-band and one broad-band channel. The narrow-band channel is intended primarily for orbital measurements in the transmission of telemetric information. It operates in the decimeter wave region. The broad-band channel, which operates in the centimeter wave range, makes it possible to transmit a broad spectrum of information from the photo-television apparatus and scientific instruments. During the flight to Mars and in orbit around it, the rate of communication with the stations will be maintained by a system of directional antennas, and if the station is oriented directly with Earth, the high-gain parabolic antenna will be employed.

The radio complex consists of receiving, transmitting and program-timing devices, a telemetric and a television system as well as an antenna feed supply.

In Mars 3, an energetically efficient method of transmitting signals from the landing craft to the ground by using the orbitting station as a relay transmitter was employed, with the orbital station in orbit around Mars. This method makes it possible to get around using complex (heavy) directional antennas and powerful transmitters and power sources in the landing craft, and to install light radio instrumentation. The radio apparatus of the mother ship is then used to transmit the information to Earth. The information which the Mars 3 station in orbit around Mars received is stored and then transmitted to Earth.

The system for supplying power to the onboard apparatus consists of a generator in the form of solar batteries and chemical power sources which consist of the floating batteries in the orbitting section and the independent batteries in the landing craft. The solar energy will suffice to charge the floating batteries during the entire flight and to power the onboard apparatus as well, which functions in the pauses between the radio communications sessions. The power to the onboard apparatus is supplied during radio communications by the floating batteries. The independent batteries on the landing craft are charged prior to its separation. The temperature control system keeps the temperature of the onboard systems of the station and the apparatus in the previously determined temperature range. On the orbitting station it consists of a vacuum insulation, special temperature regulating layers and active gas circulation systems of a closed variety with a heating radiator, which is constantly turned towards the Sun and a cooling radiator which is always in the shade. The gas which fills the instrument compartment is used as a heat carrier. Constant circulation of the heat carrier is ensured by a ventilation device.

The mechanism for repeated utilization ensures correction of the flight path during the flight and the braking during transition to the orbit of an artificial Mars satellite. It consists of a fluid jet mechanism with a pumping system to supply the fuel components, a control device and the fuel containers.

Time Table For the Most Important Days of the Flight

The Mars 2 station was launched on 19 May 1971 at 1722:49 CET; Mars 3 was launched on 28 May 1971 at 1626:30 CET. Entry of Mars 2 into the aerocentric orbit took place on 27 November 1971 at 2119

The landing of the Mars 3 took place as follows: separation from the mother ship on 2 December 1971 at 1014. Landing engine of Mars 3 switched on at 1029. Entrance into the upper layers of the Martian atmosphere at 1444. Soft landing on Mars on 2 December 1971 at 1447:30. Landing of Mars station on the planetary surface in working position at 1449. Beginning of transmission of a video signal from the Martian surface at 1450:35 (all times in CET).

Captions of Figures Not Reproduced.

Below: Landing Capsule of Automatic Interplanetary Research Station Mars 3 With Parachute Container (Top). The flexible cords (still loose) for fastening the parachute container to the lower part of the automatic Mars station are clearly visible. At the bottom of the AMS is the nozzle of the rocket motor. Right: Picture of Planet Mars Taken From a Distance of 50,000 km, Using the Mars 3 Camera With a 52 mm Objective. Photos: TASS

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